Broadside Parallel-plate Slot Antenna without Dielectric

M.Vera-Isasa , Á. Álvarez , M.Sierra-Castañer , M.Sierra-Pérez

Abstract

A linearly polarized flat antenna with broadside beam radiation is presented in this paper. A rectangular slot array in the upper side of a parallel plate wave-guide form the main antenna structure. In previous works, the authors have presented one and dual tilted-beam antennas [1-2] for the reception of Hispasat or Astra satellite emissions in the 12 GHz band. The problem of the broadside beam antenna is to avoid the grating lobes. The main goal of the work presented here is getting a low cost broadside antenna that does not need a dielectric material inside the parallel plate to solve the grating lobes problem.

I. Antenna structure

The antenna structure consists on two metallic plates. The upper one will support the slot-printed antenna, while the ground plane supports the feeding structure. The space between the plates is less than half guided wavelength, son only the fundamental TEM mode is propagated. Fig. 1 shows a schematic section of the antenna structure.

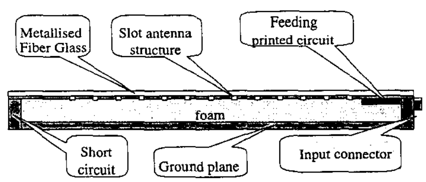

Fig. 1. Scheme of the transmission line section.

The slots printed in the upper plate are all of them parallel to the others, so the antenna is linearly polarized. The antenna is fed along one of the sides parallel to the slots with a linear array of feeding elements like the described in [1-2]. This is shown in figure 2. To get a plane feeding wave inside the guide an array of rectangular patches were placed in the side of the antenna and fed with equal amplitude and phase [1-2]. In this form, a travelling plane wave inside the parallel plate is achieved and the electric field under the slots can be described by

$$\overline{E}_{in} = \hat{z}\, E_0 \exp\{-jk_g x\} \quad (1)$$

where E_0 is electric field amplitude in x=0 and $k_g=\omega(\mu\varepsilon)^{1/2}$ with μ and ε are the permeability and permitivity of the dielectric material inside the parallel plate.

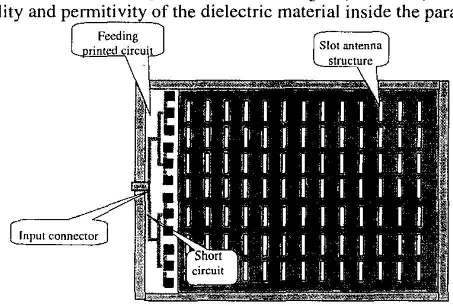

Fig. 2. Scheme of the antenna structure.

II. Slot array

Columns of resonant slots printed in the upper plate form the radiating structure. Each column acts as a full radiating element in a travelling wave antenna. All the slots must be excited in phase to get a broadside radiation beam so, according to (1), the space between successive columns must be equal to one guided wavelength. If there is no dielectric inside the parallel plate, the space between the slot columns will be equal to the free space wavelength and grating lobes appear in both the directions of the E-plane radiation pattern ($\theta=\pm\pi/2$).

Additional columns of slots placed between the one wavelength separated ones are needed to avoid the grating lobe problem. Since the inner field, as can be deduced from (1), does not excite these added slots with the same phase than the previous, then the principal radiation beam will not broadside.

However, the radiation phase of the field induced in the slot aperture depends not only on the phase of the guided field under the slot but also on the slot length [3]. It is possible to adjust the slot length to control the phase excitation along the antenna aperture.

A radiation element composed by two slots is proposed: one slot must be longer and placed nearer de feed than the resonant length slot and the other must be shorter and placed far than the resonant one. The lengths of the slots in each pair must be selected properly to compensate the phase difference due to the exciter guided field (1), that is,

$$\Delta\phi = \phi_2 - \phi_1 = k_g d \quad (2)$$

where $\phi_{1,2}$ are the phases of the longer and shorter slots, respectively and d is the distance between them.

The theoretical improvement that can be achieved in the radiation level at the grating lobe positions as a function of the slot-pair electric distance, d/λ_0, is shown in figure 4.

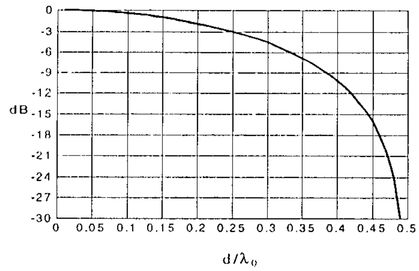

Fig. 3. Grating lobe level improvement

III. Results

Two designs have been analyzed with a method that takes into account the mutual coupling between the slots both inside and outside the parallel plate [4]. In the first design, the distance between the two slots in a pair is a quarter wavelength, the slots lengths are $0.59\lambda_0$ and $0.43\lambda_0$. The radiation pattern obtained for a 20 slot pair element antenna is shown in figure 4. The second proposal is a half wavelength separated slot pair, with lengths $0.95\lambda_0$ and $0.29\lambda_0$, whose radiation pattern is shown in figure 5.

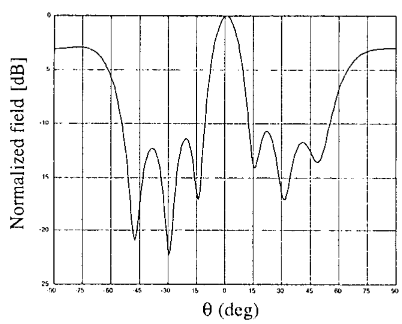

Fig. 4. E-plane pattern for a 5×4 quarter wavelength separated slot pairs

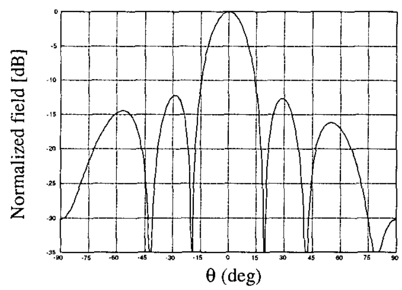

Fig. 5. E-plane pattern for a 5×4 half wavelength separated slot pairs

The results are in concordance with the theory. The half wavelength separated slot pairs present a strong grating lobe reduction but the slot coupling is small due to the slot lengths and the antenna radiation efficiency is poor. The quarter wavelength separated slot pair shows smaller grating lobe reduction but the antenna efficiency is better. So there is a compromise solution between these two radiation properties.

IV. Conclusions

A design method for the synthesis of broadside-beam linearly polarized slotted parallel-plate antenna has been presented. This contribution studies the possibility of employ this kind of antenna without dielectric inside the parallel-plate structure to reduce the fabrication cost of the antenna. The results are very promising and actually we are preparing a prototype. Measurements will be showed at the conference.

Acknowledgements

This work is included into the European project FEDER numbered 1-FD97-0276-C02-02. We want to thank the financial supporting from FEDER, CICYT and TELEVÉS S.A.

References

[1] M.S. Castañer, J. Izquierdo, M. Sierra, J.L. Fernández, M. Vera, "Linear polarization parallel plate slot antenna", IEEE AP-S, vol.3, pp.1608-1611, Salt Lake City, Utah, July 2000.

[2] M.S. Castañer, M. Sierra, J.L. Fernández, M. Vera, O. Moreno "Dual Beam Parallel Plate Slot Antenna", AP-2000 Millenium, Davos, Suiza, April 2000.

[3] M. Vera Isasa, Antenas de Ranuras en Guía Radial. Análisis, Diseño y Aplicaciones, Ph. D. Dissertation, University of Vigo. 1996

[4] M. P. Sierra, M. Vera, A. G. Pino, M. C. Sierra, "Analysis of slot antennas on a radial transmission line", Int. J. of MiMiCAE, vol.6, n°2, pp.115-127, March 1996.